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ABSTRACT

Results of observations and of students' performance on pretest/posttests suggest that almost all students enter the fifth grade with certain fundamental misconceptions about light and how people see. Unfortunately, fifth grade science textbooks often fail to inform teachers about these misconceptions or to suggest a teaching strategy that will help teachers with them. Therefore, 13 transparencies were developed for use with the unit on light found in the fifth-grade textbook "Exploring Science" by M.K. Blecha, P.C. Gega, and M. Green (1979, Laidlaw Brothers). The transparencies (keyed to an appropriate page in the text) and this manual were designed to help teachers understand common student misconceptions about light and change those student misconceptions to scientific or goal conceptions. The manual contains: (1) an introduction describing how the transparencies are to be used; (2) illustrations of the transparencies and a commentary contrasting student answers to the questions posed with the correct "textbook" answers; and (3) three tables contrasting common student misconceptions (naive beliefs) with scientific or goal conceptions on a number of topics related to light and seeing, pathways of light, and color. (JN)

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Research Series No. 130

TRANSPARENCIES ON LIGHT: TEACHER'S MANUAL

Charles W. Anderson and
Edward L. Smith

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Abstract

This manual was used during the second year of the Elementary Science Project. Teachers were provided with the manual and a set of 13 transparencies, shown as illustrations in the manual. The teachers used the transparencies in conjunction with the light unit from the fifth-grade textbook, *Exploring Science*. The transparencies can also be used independently. The manual and transparencies are to help teachers understand common student misconceptions about light and change those student misconceptions to scientific or goal conceptions. This manual contains (1) an introduction describing how the transparencies are to be used, (2) illustrations of the transparencies and a commentary contrasting common student answers to the questions posed with the correct or "textbook" answers, and (3) tables contrasting common student misconceptions about light with scientific or goal conceptions.

TRANSPARENCIES ON LIGHT: TEACHER'S MANUAL[1]

Charles W. Anderson and Edward L. Smith[2]

Purpose of this Manual

This manual will be useful in helping your students better understand the unit on light in *Exploring Science* (Blecha, Gega, & Green, 1979), a fifth-grade textbook.

This manual and the transparencies that accompany it arise from the work of the Elementary Science Project at the Institute for Research on Teaching, Michigan Sate University. During the 1981-82 school year we observed teachers as they taught the unit. In addition to observing science classes, we administered pretests and posttests to the students in these classes in order to evaluate their understanding of light and seeing before and after instruction.

As a result of our observations and of the students' performance on the pretests and posttests, we are convinced that almost all students enter the fifth grade with certain fundamental *misconceptions* about light and how people see. These misconceptions are quite reasonable and understandable. In fact, they are often reinforced and encouraged by the way people talk about light and seeing in their everyday language. However, the students can adequately understand the material in the text *only* if they replace their misconceptions with more advanced or "scientific" beliefs.

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[1]This manual is a product of the Elementary Science Project, which is funded by a National Science Grant, No. SED 8020022. This manual does not necessarily reflect the official position, policy, or opinions of the National Science Foundation.

[2]Charles W. Anderson is a researcher in the IRT, co-coordinator of the Elementary Science Project, and an assistant professor of teacher education at Michigan State University. Edward L. Smith is a researcher in the IRT, co-coordinates the Elementary Science Project and is coordinator of the Conceptual Change Project. He is an associate professor in administration and curriculum.

Unfortunately, the text often fails to inform teachers about the misconceptions or to suggest a teaching strategy that will help teachers deal with them. Therefore, we have designed a series of transparencies that can be used to supplement the *Exploring Science* text. This manual describes what the transparencies are and how to use them. (Transparencies themselves are not included herein, but a paper copy of each transparency illustration has been included.

How to Use the Transparencies

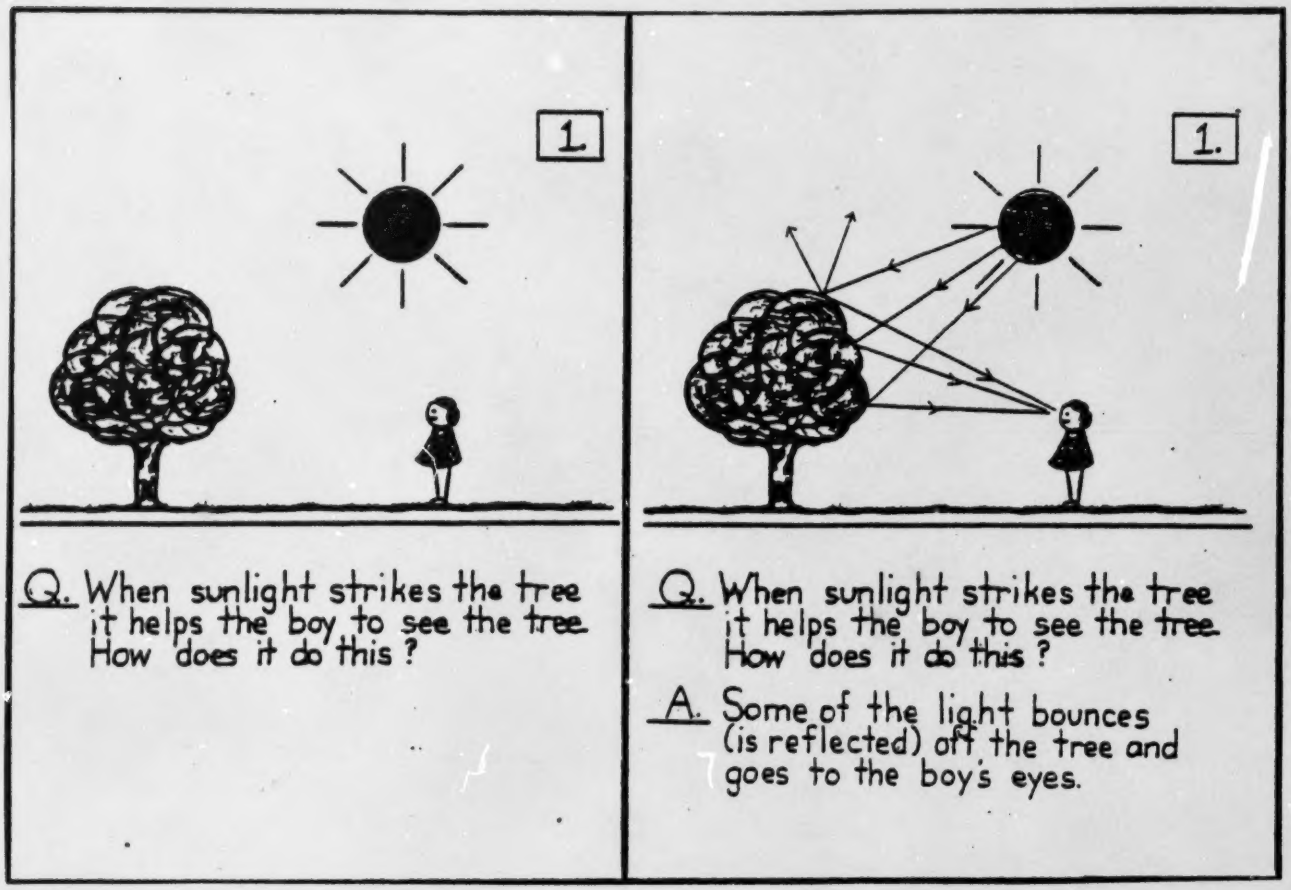
Each of the transparencies has two layers. The bottom layer describes a situation and poses a question about that situation. After your students have tried to answer the question, you can flip down the overlay to give them the scientific or "textbook" answer to the question.

You will find that your students' answers are often very different from those proposed by the textbook. We believe that it is *essential* for the students to have the chance to answer the questions, then see the contrast between their answers and the textbook answers. It is only through such explicit contrast that students will see the need for abandoning their misconceptions in favor of more sophisticated conceptions.

The students do not need to be embarrassed or ashamed if they answer a question incorrectly. What we now call misconceptions were the most advanced scientific ideas for many centuries. It is the newer scientific ideas that seem strange, not the students' commonly held ideas.

This manual will describe some common student answers to each of the questions, reveal the misconceptions that underlie those answers, and contrast the students' answers with the textbook answers. The charts at the end of the manual contrast naive, student beliefs with scientific beliefs on a number of topics related to light and seeing. Each transparency is keyed to an appropriate page in the *Exploring Science* text.

Descriptions of Individual Transparencies


1.
Q. When sunlight strikes the tree it helps the boy to see the tree. How does it do this?
1.
Q. When sunlight strikes the tree it helps the boy to see the tree. How does it do this?
A. Some of the light bounces (is reflected) off the tree and goes to the boy's eyes.

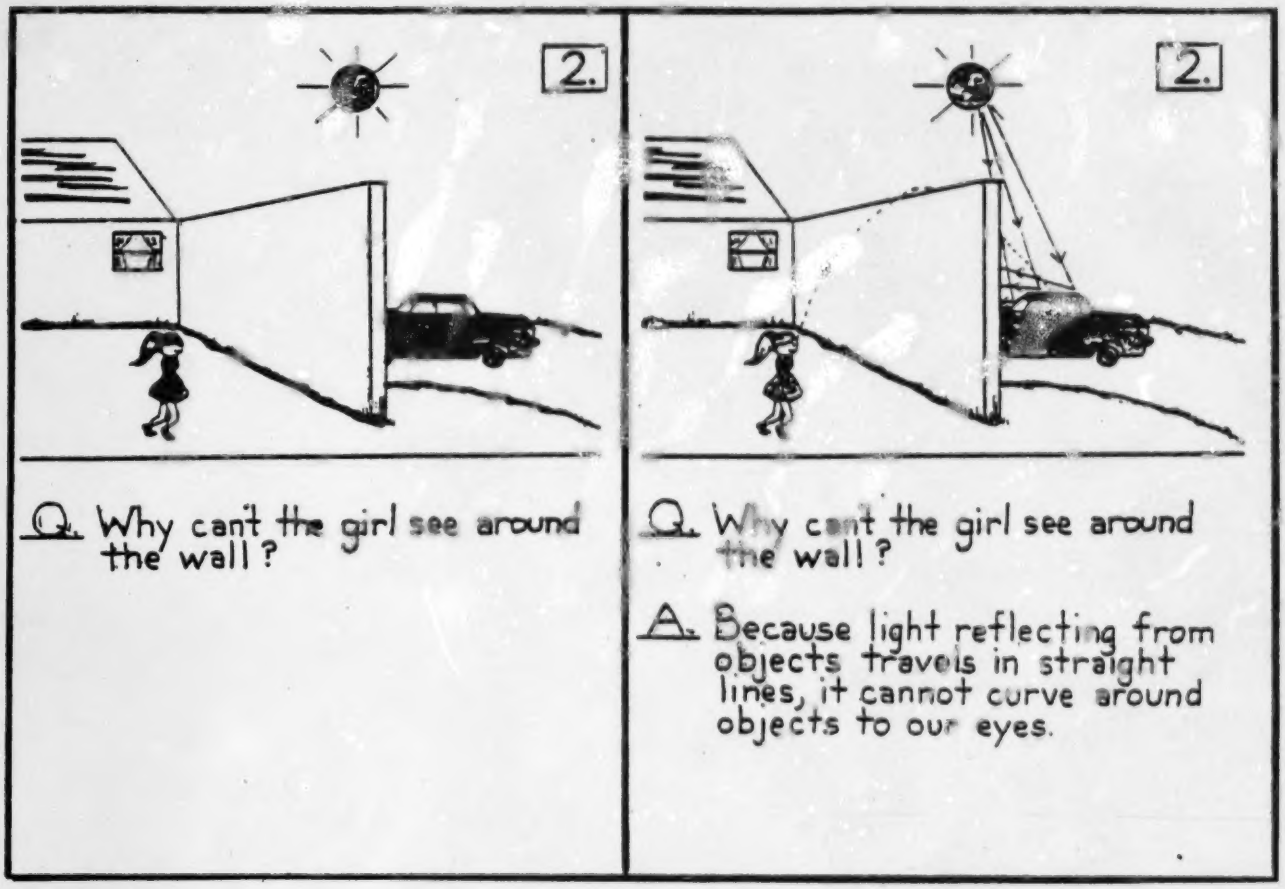
1. How Light Helps Us to See (page 145)

Common student answers. Many of your students will probably give answers like these to the question:

"The sun shines on the tree."
"The light makes it brighter."
"You can't see in the dark."

Although these answers are not wrong, we find that children who give answers like those above often do not understand the role that *reflected light* plays in seeing. They tend to believe that we see objects directly rather than detecting light that is reflected from objects. They also commonly think of light as a condition (like warmth), rather than as a form of engergy that travels through space.

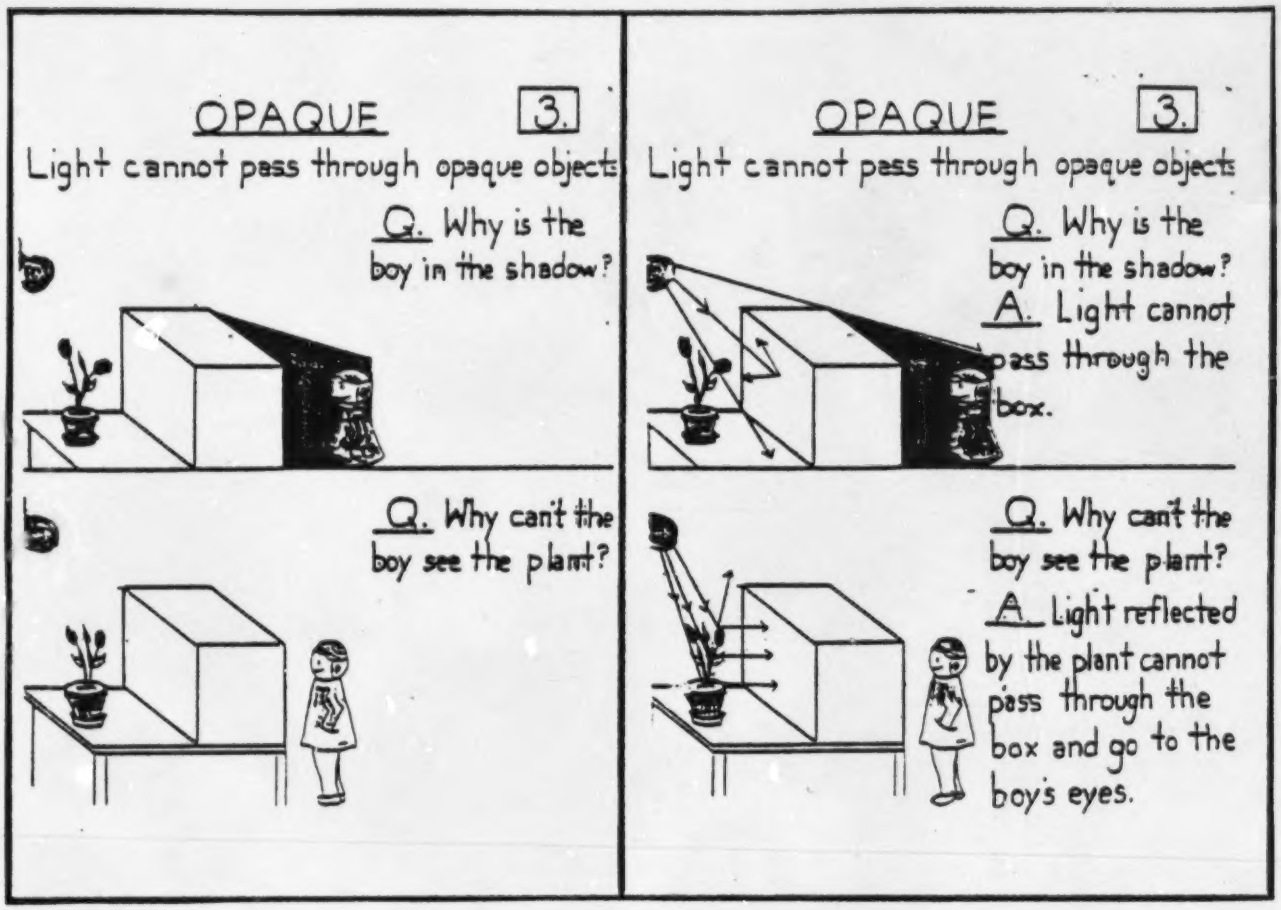
Textbook answer. The arrows on the transparency make it possible for you to follow the path that light takes to the boy's eyes. Notice that the boy does not see the object directly. Instead he sees the light that is from the tree and reaches his eyes.


2.
Q. Why can't the girl see around the wall?
2.
Q. Why can't the girl see around the wall?
A. Because light reflecting from objects travels in straight lines, it cannot curve around objects to our eyes.

2. Light Travels in Straight Lines (page 148)

Common student answers. Your students will probably know that the line of sight is a straight line. They will know that the girl can't see the car because "the wall is in the way." But is the wall in the way of? Many students may say that the wall is in the way of the girl's "vision" or "eyes."

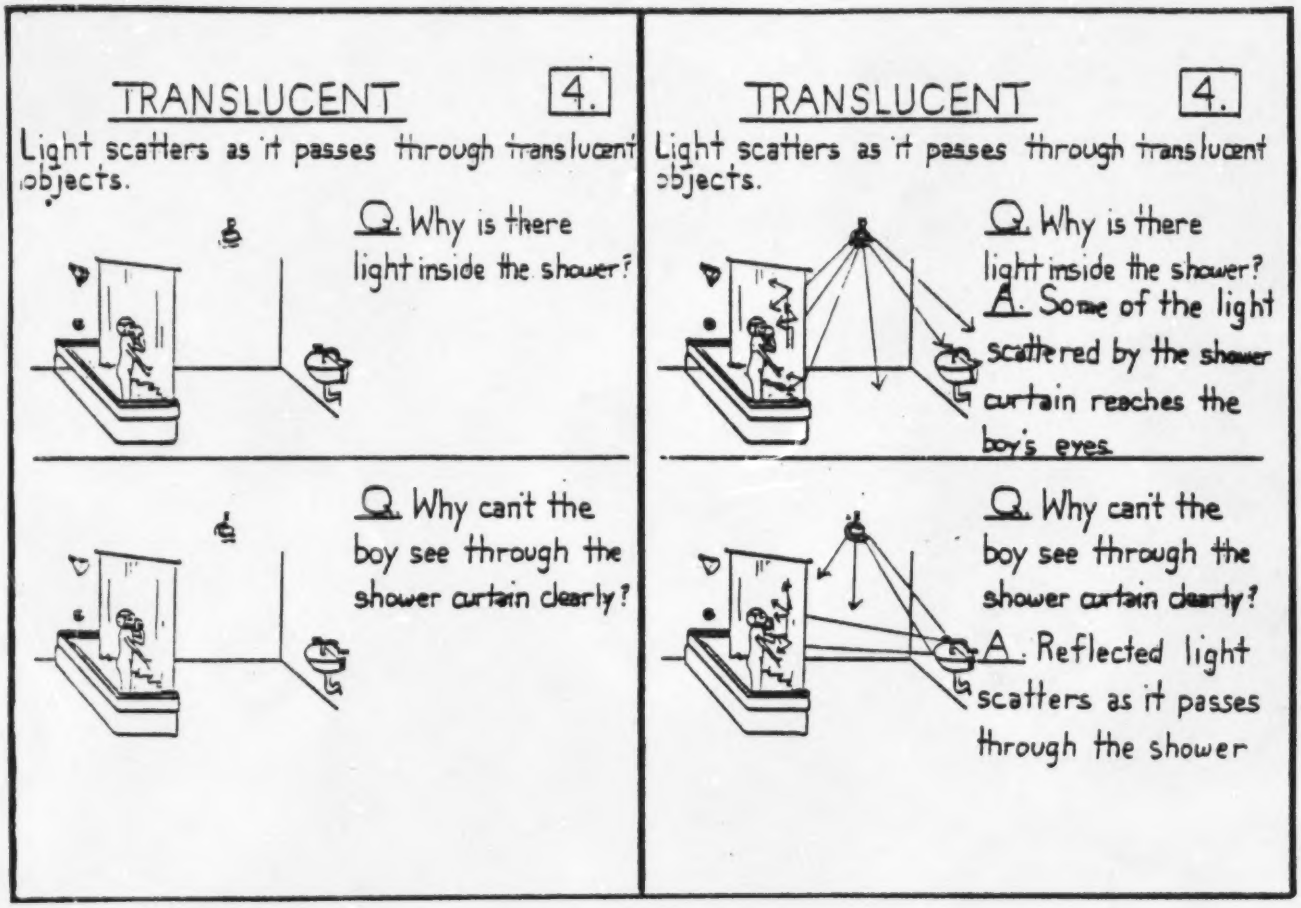
Textbook answer. The wall is really in the way of the *light* reflected from the car. It prevents the light that reflects off the car from getting to the girl's eyes. Because the light travels in straight lines, it does not curve over or around the wall, so the girl cannot see the car. The girl cannot see the car unless light is reflected off it to her eyes.


OPAQUE
3.
Light cannot pass through opaque objects
Q. Why is the boy in the shadow?
Q. Why can't the boy see the plant?
OPAQUE
3.
Light cannot pass through opaque objects
Q. Why is the boy in the shadow?
A. Light cannot pass through the box.
Q. Why can't the boy see the plant?
A. Light reflected by the plant cannot pass through the box and go to the boy's eyes.

3. Opaque Objects (page 149)

Common student answers. Many students will answer the two questions in different ways. They will explain the shadow in the first question by saying that the light from the bulb cannot pass through the box. In the second question, they will explain that the boy can't see the book, however, because "you can't see through opaque objects." Once again, the students think of opaque objects as blocking *vision* rather than blocking the light reflected from the book.

Textbook answer. It is important to notice that the same idea answers both questions. The shadow is created because the light from the bulb cannot pass through the box. The boy can't see the book because the light reflected by the book cannot pass through the box.

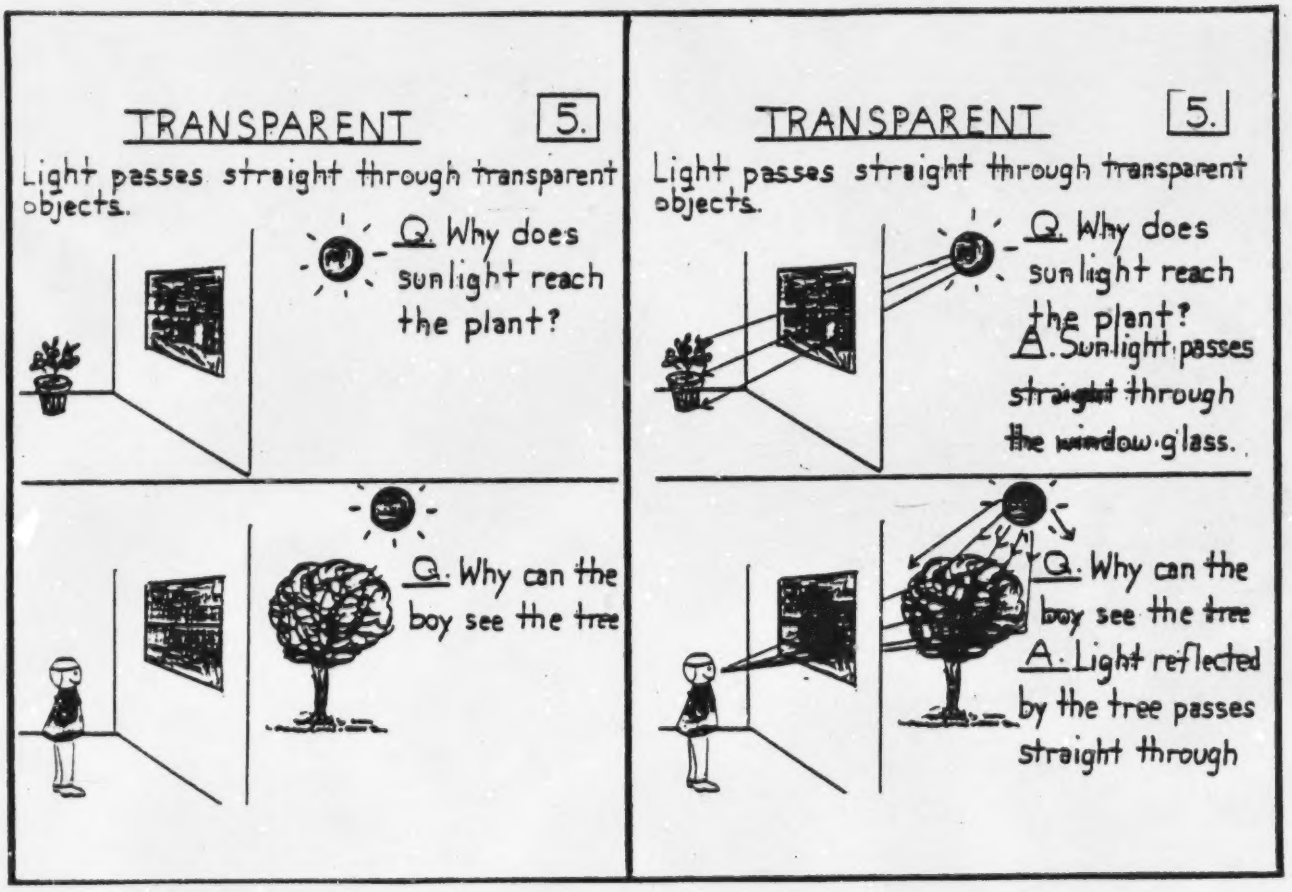

TRANSLUCENT
4.
Light scatters as it passes through translucent objects.
Q. Why is there light inside the shower?
Q. Why can't the boy see through the shower curtain clearly?
TRANSLUCENT
4.
Light scatters as it passes through translucent objects.
Q. Why is there light inside the shower?
A. Some of the light scattered by the shower curtain reaches the boy's eyes
Q. Why can't the boy see through the shower curtain clearly?
A. Reflected light scatters as it passes through the shower

4. Translucent Objects (page 149)

Common student answers. Students who do not think of seeing as detecting reflected light will tend to give different answers to the two questions.

"There is light inside the shower because the light can get through the shower curtain."
"The boy can't see through the shower curtain because it makes things look blurry."

Textbook answer. Light is scattered as it passes through translucent objects. This idea explains both situations. Light from the room goes through the shower curtain, but the image is not clear because the light is scattered.

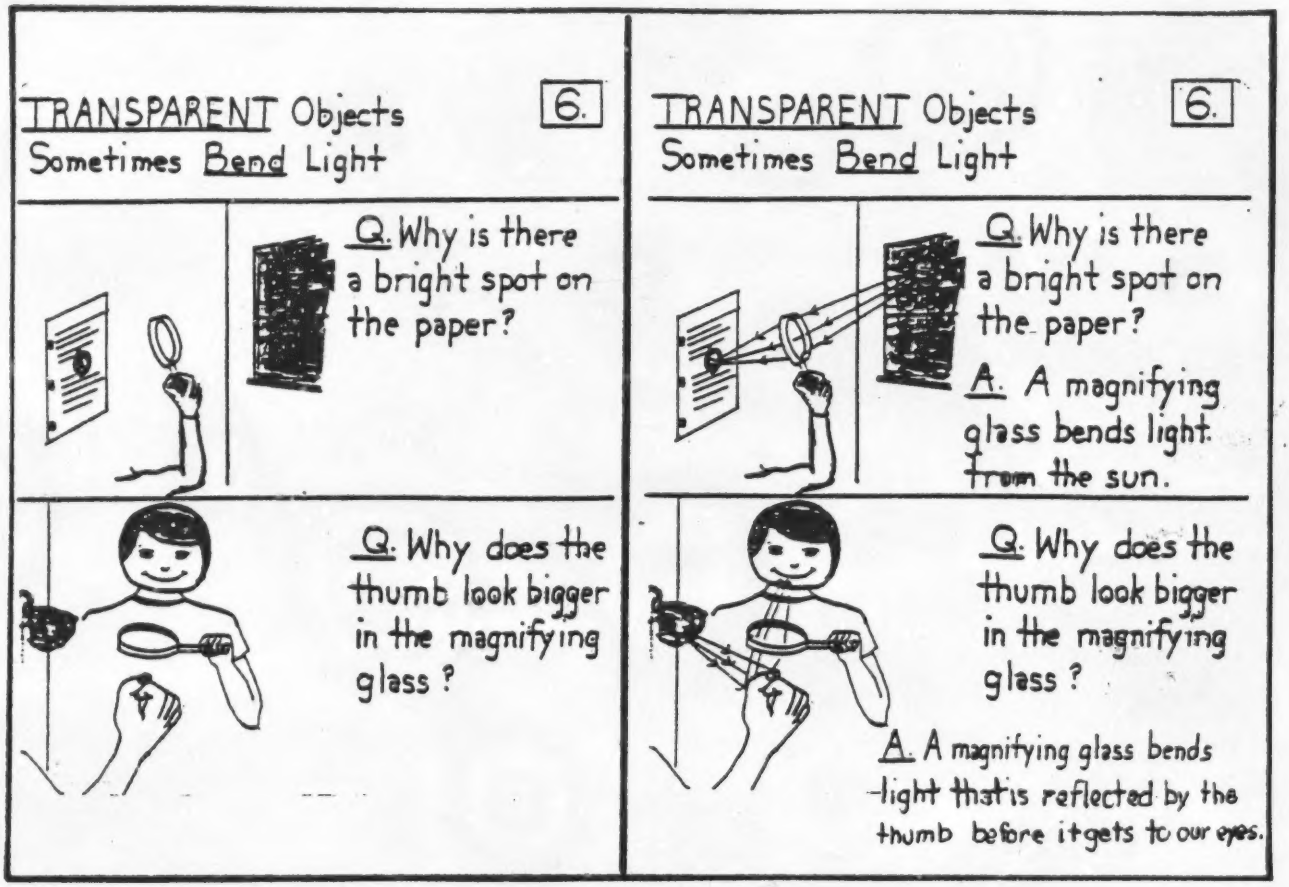

TRANSPARENT
5.
Light passes straight through transparent objects.
Q. Why does sunlight reach the plant?
Q. Why can the boy see the tree
TRANSPARENT
5.
Light passes straight through transparent objects.
Q. Why does sunlight reach the plant?
A. Sunlight passes straight through the window glass.
Q. Why can the boy see the tree
A. Light reflected by the tree passes straight through

5. Transparent Objects (page 150)

Common student answers. Students who do not think of seeing as detecting reflected light will tend to answer the two questions differently:

"The sunlight goes straight through the glass."
"The boy can see through the window."

Textbook answer. The idea the light passes straight through the window glass can be used to explain both situations. The sunlight travels straight through the window glass to the plant, and the light reflected off the tree travels straight through the window glass to the boy's eyes. Notice that when we "look out the window," we are actually detecting light that is coming through the window.


TRANSPARENT Objects
Sometimes Bend Light
6.
Q. Why is there a bright spot on the paper?
Q. Why does the thumb look bigger in the magnifying glass ?
TRANSPARENT Objects
Sometimes Bend Light
6.
Q. Why is there a bright spot on the paper?
A. A magnifying glass bends light from the sun.
Q. Why does the thumb look bigger in the magnifying glass ?
A. A magnifying glass bends light that is reflected by the thumb before it gets to our eyes.

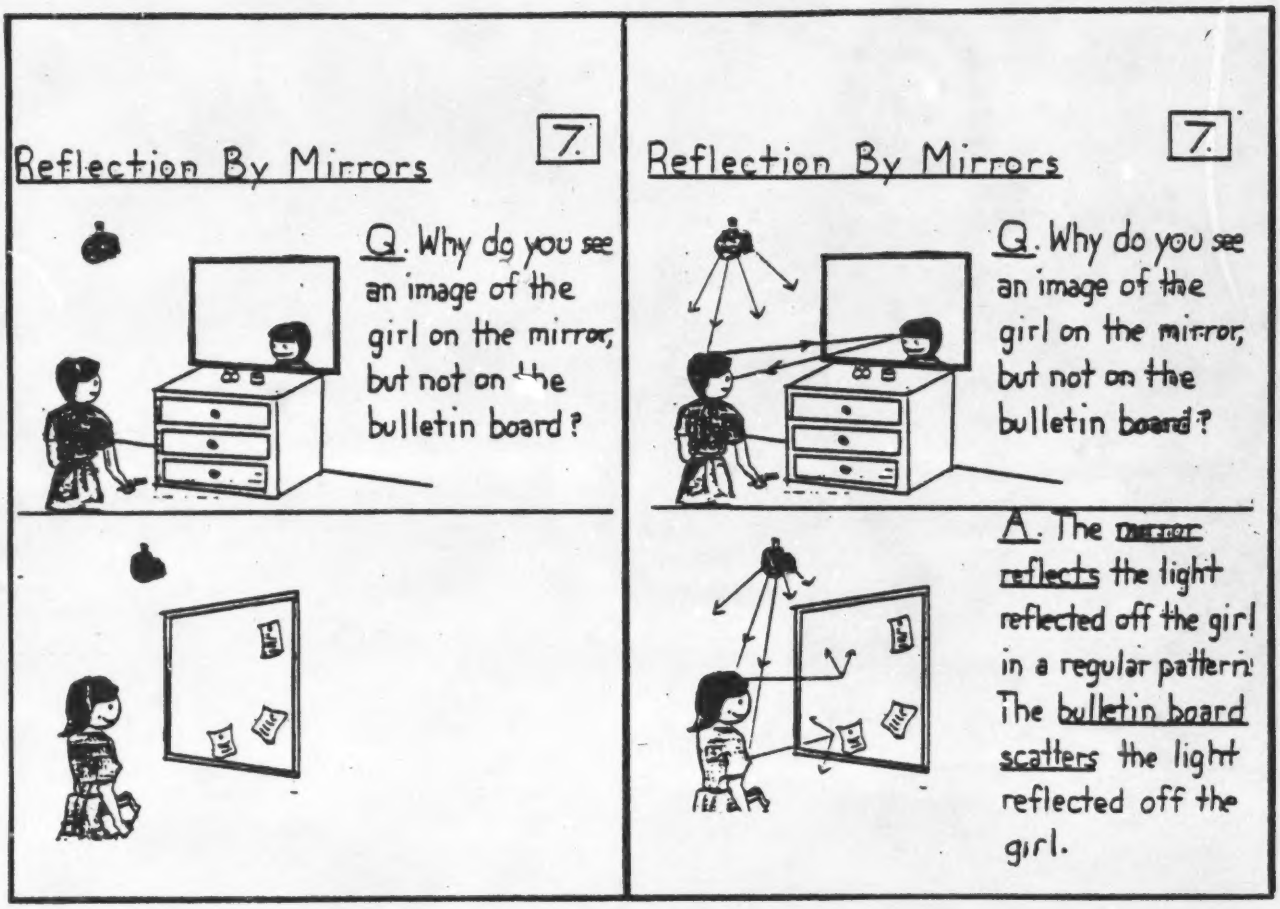
6. Transparent Objects Sometimes Bend Light (pages 150-52)

Common student answers. Most students will probably realize that "bending light" has something to do with the answers to the questions. However, they will probably have difficulty describing where the light is coming from and where it is going after it is bent.

Textbook answer. When you "look through" transparent objects, the appearance of what you see is sometimes changed. This is because the reflected light is bent by the transparent object before it reaches your eyes. The nature and shape of the transparent object determine how much light is bent and therefore how much of the appearance of the object being viewed "through" it is changed.

Magnifying glasses that are used to focus sunlight and projectors of all kinds also bend light. In this case, they bend light from a light source rather than reflected light.

Students usually enjoy the "Finding Out" activities on pages 151 and 152, but many students view the situation without applying their knowledge of light to explain their observations. You can help them take this crucial step by discussing how the water bends light in each case.

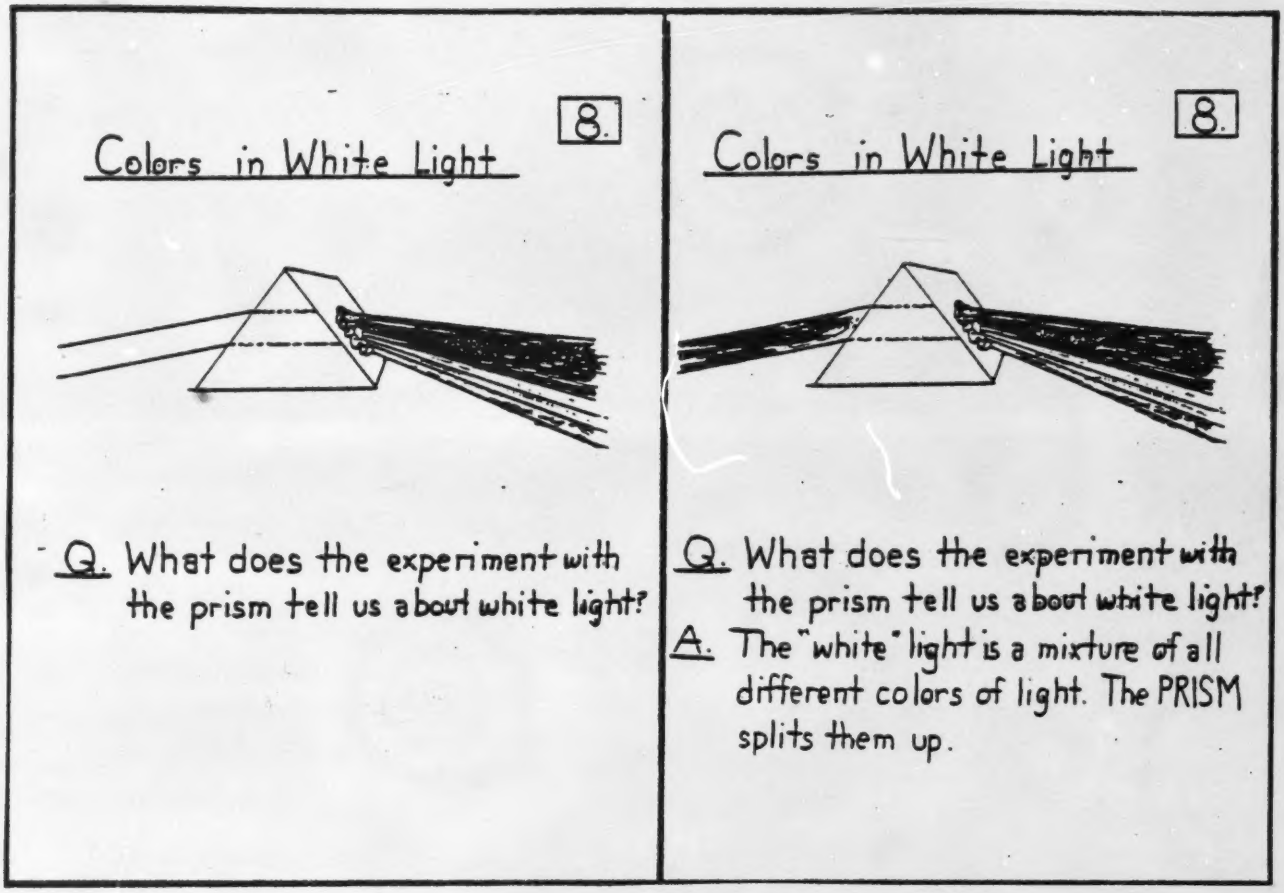

Reflection By Mirrors
7.
Q. Why do you see an image of the girl on the mirror, but not on the bulletin board?
Reflection By Mirrors
7.
Q. Why do you see an image of the girl on the mirror, but not on the bulletin board?
A. The mirror reflects the light reflected off the girl in a regular pattern. The bulletin board scatters the light reflected off the girl.

7. Reflection by Mirrors (page 155)

Common student answers. Many students will say that "the mirror reflects but the paper doesn't." This answer contradicts what the students should already know about how objects reflect light. A somewhat more sophisticated answer is that "the mirror reflects images but the bulletin board reflects only light." This answer also is not entirely correct. Images do not travel through the air, only light. We see images when there is a regular pattern in the light reaching our eyes.

Textbook answer. Actually, both the mirror and the bulletin board reflect light. However, the bulletin board *scatters* the reflected light and the mirror does not. The scattering destroys the regular pattern in the light.

Notice the complicated path that the light has to take in order for us to see ourselves in the mirror. Light from a light source bounces off of us, then off the mirror, then back to our eyes.

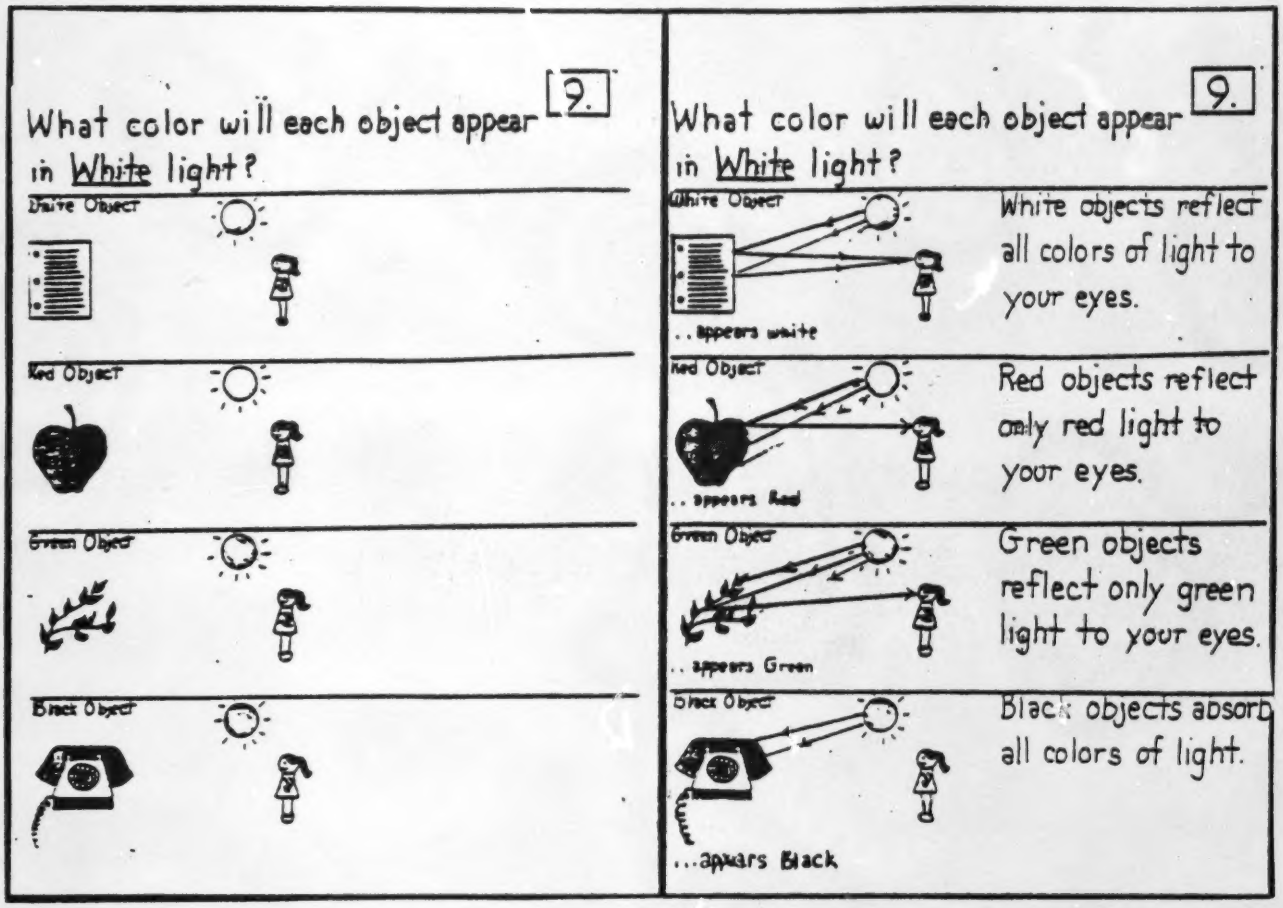

8.
Colors in White Light
Q. What does the experiment with the prism tell us about white light?
8.
Colors in White Light
Q. What does the experiment with the prism tell us about white light?
A. The "white" light is a mixture of all different colors of light. The PRISM splits them up.

8. Colors in White Light (page 159)

Common student answers. Many students think of white light a being "pure" or "colorless." Students who believe this are likely to think that the prism somehow "makes" the colors of the spectrum. A related belief is that color can somehow be "added" to white light much as color can be added to white paint.

Textbook answer. In fact, white light is exactly the opposite of pure or colorless. It is a mixture of all the colors of the spectrum. We see white or "colorless" light when all wavelengths (colors) of visible light are mixed. Thus color is a property of light, something that light already has, rather than something that can be added to light. (We make white light into red light by taking out all the colors in the white light except red.)

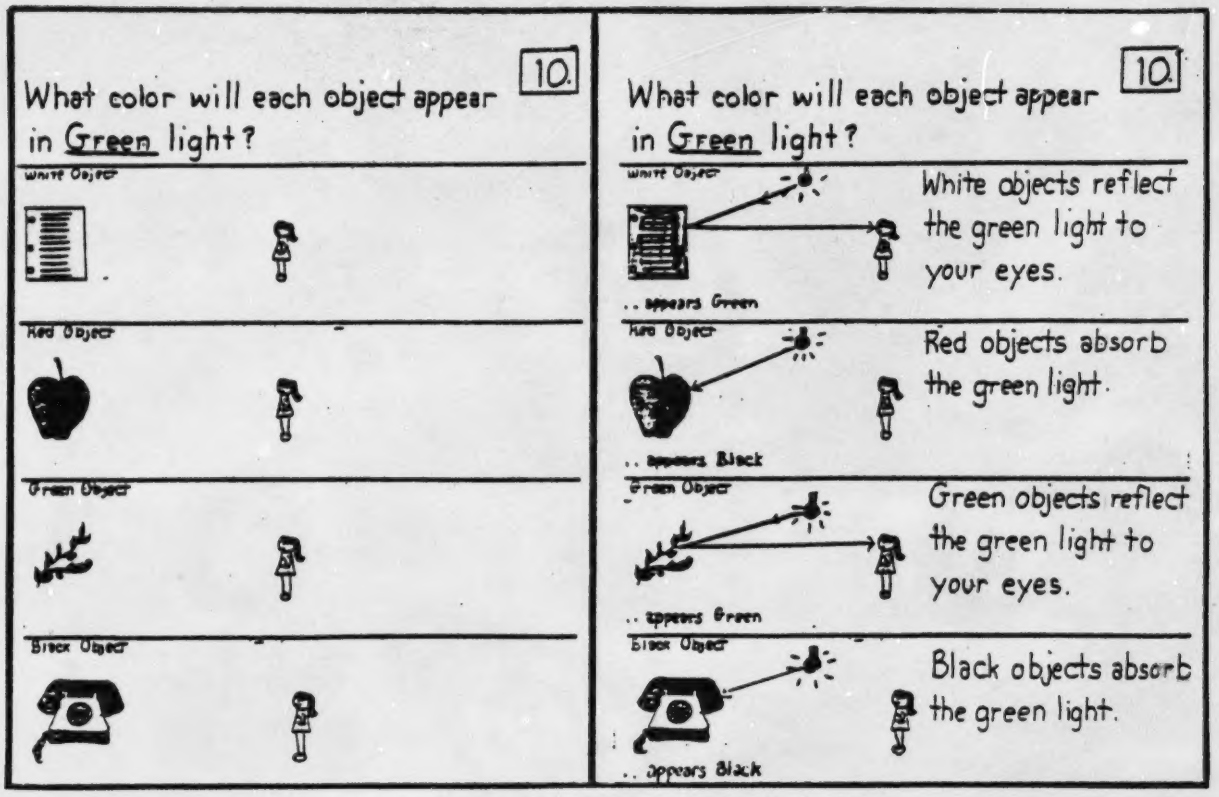
We can see the colors when white light shines through a prism because the glass in the prism bends some colors of light more than it bends others. The prism therefore, separates the white light into its component colors.


What color will each object appear in White light? 9.
White Object
Red Object
Green Object
Black Object
What color will each object appear in White light? 9.
White Object
..appears white
White objects reflect all colors of light to your eyes.
Red Object
.. appears Red
Red objects reflect only red light to your eyes.
Green Object
.. appears Green
Green objects reflect only green light to your eyes.
Black Object
...appears Black
Black objects absorb all colors of light.

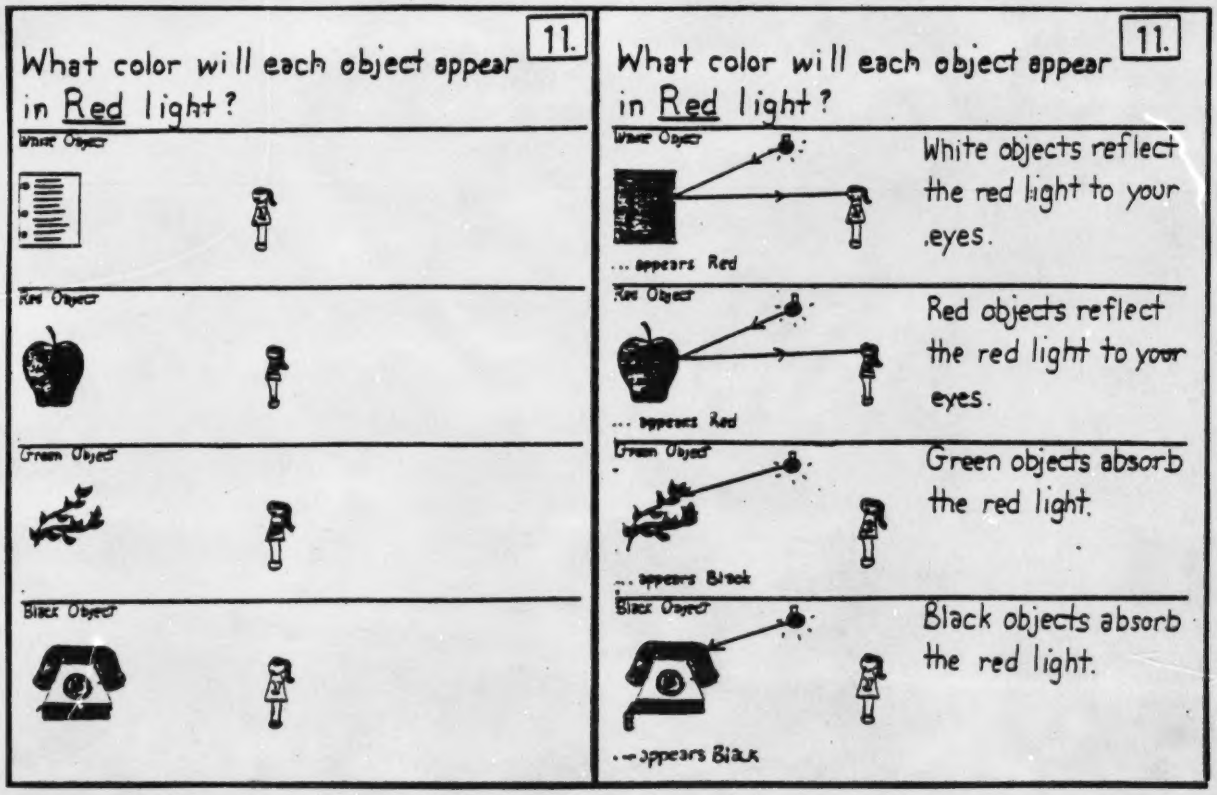
9. Colors of Objects in White Light (page 164)

Common student answers. All of your students will undoubtedly be able to correctly predict the colors that each object will appear. However, many will probably have incorrect explanations, saying that the apple appears red "because it is red." This answer implies that the color somehow resides in the object, and the light simply "reveals" that color.

Textbook answer. In fact, we see the color of the *light* that reaches our eyes. An object that appears white is reflecting all colors of light to our eyes. An object that appears black is reflecting virtually no light to our eyes. An object that appears red is reflecting red light to our eyes.



10. Color of Objects in Red Light (page 166)



11. Color of Objects in Green Light (page 166)

Common student answers. Pay special attention to what the students say about the red apple in green light and the green plant in red light. They will rarely make a correct prediction. For instance, some students say that the apple in green light will look *red*. Students who make this prediction are thinking of color as a property of objects rather than as a property of light. Other students may focus exclusively on the color of the light and predict that the apple will appear *green*. They are forgetting that the pigments in the apple absorb green light. Still other students may try to mix the colors, predicting that the apple will appear *reddish-green*.

Textbook answer. The theory presented in the textbook predicts that the apple will appear *black*. If the apple reflects only red light, and only green light is reaching the apple, then the apple will not reflect any light at all.

Note. In fact, the theory leads to correct predictions only if both the green light and the red pigment are almost pure. The "Finding Out" activity on page 167 probably will not work very well if you try it. There are several reasons for this:

1. Unless the room is in total darkness, some white light is leaking into the room, and students will see the white light reflected off of objects.

2. Ordinary cellophane does not produce pure colored light. It lets some of all colors of light through. Thus the green light probably still include some red light.

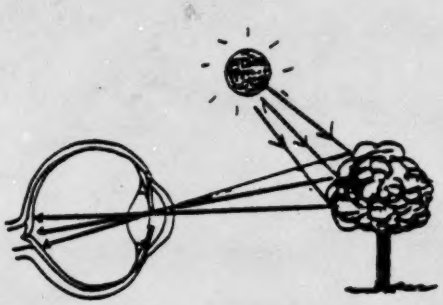
3. The pigments in common everyday objects do not really absorb every color of light except one. An apple appears red because it reflects somewhat more red light than other colors of light.

For all these reasons, the results of the "Finding Out" activity on page 167 are very difficult to predict.

12.

Q. When you see a tree, light comes into your eyes. Where does the light come from?

12.

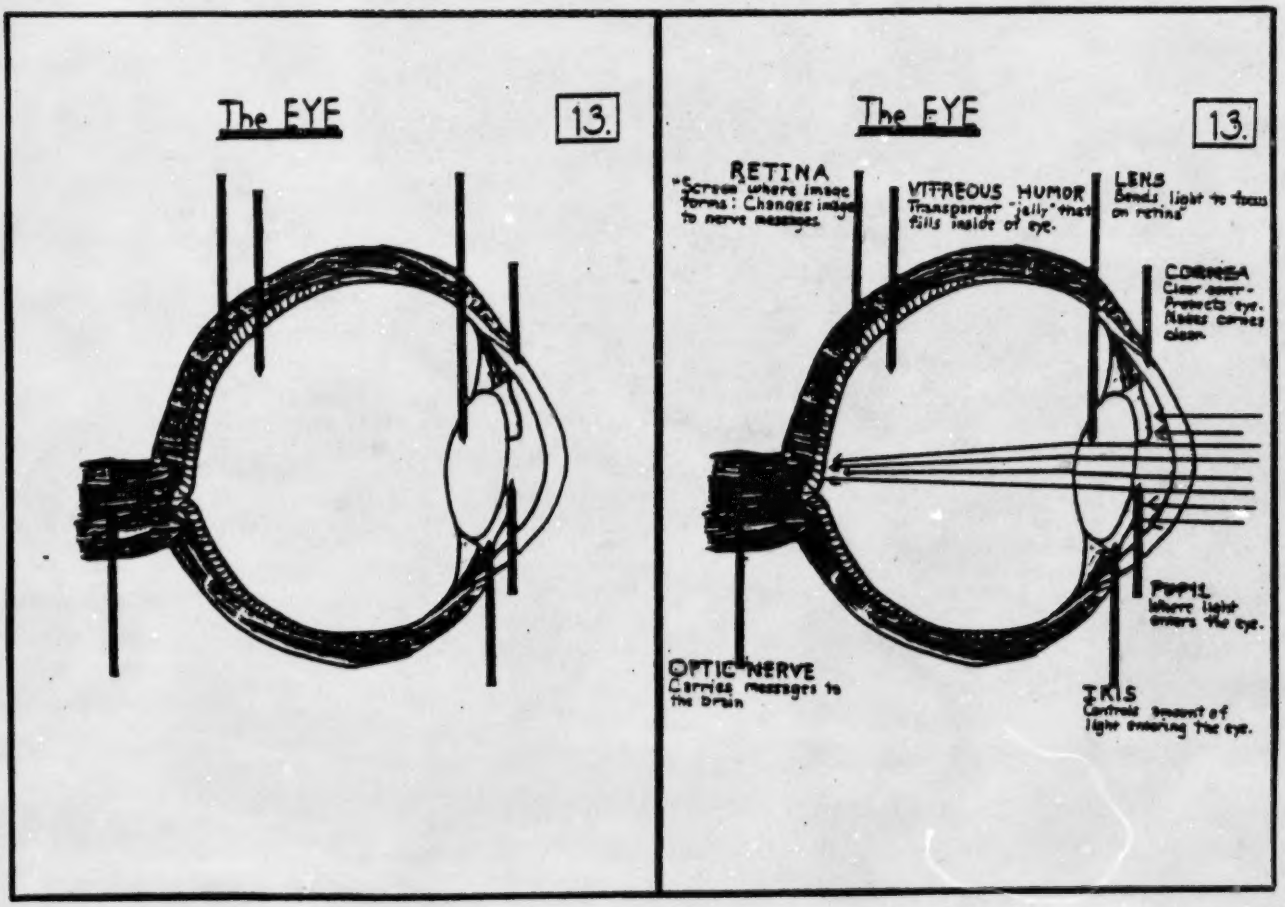


Q. When you see a tree, light comes into your eyes. Where does the light come from?

A. First the light comes from the sun, then it bounces off the tree and comes to your eyes.

12. Light Entering the Eyes (page 169)

We have found in the past that many students fail to connect what they learn about the eye parts in Chapter Three with their previous discussion of seeing in Chapter One. This transparency is designed as a reminder to help them make those connections. In particular, the transparency is designed to remind students that the light entering our eyes is light that has been reflected off of objects.



13. Function of Eye Parts (pages 169-70)

We have found that many students can name the eye parts without really understanding what those parts do. In particular, they may have trouble understanding how all of the parts function *together* to make vision possible. Students seem to have the most difficulty with the retina, optic nerve, and brain. Many students believe that the optic nerve somehow carries light or picture to the brain. The idea that the brain functions in total darkness, translating nerve messages into what we see, is hard for many students to accept.

When you use this transparency try to emphasize the *story* of how we see: how light enters the eye, is focused on the retina, and is translated into nerve messages that are received and interpreted by the brain. You may want to give a few students a chance to see if they can tell the whole story, describing the function of every part.

Student Misconceptions Contrasted With Textbook Answers

The charts below are based on our observations and our analysis of students test responses. We have found that common student ideas differ from the ideas presented in the text in a variety of respects. Many of these differences have been discussed in the body of this manual. The purpose of the charts is to present the contrasts in a concise manner.

Chart 1.

Conceptions of Light and Seeing

Children believing in a naive conception believe that we see objects directly, rather than detecting light reflected off of objects.

	TOPIC	NAIVE CONCEPTION	GOAL CONCEPTION
1.	Nature of light.	1. Light is a condition, existing in space.	1. Light constantly travels through space.
2.	Interaction of light and objects.	2. Light brightens or shines on objects.	2. Light reflects or bounces off of most objects.
3.	Function of eyes.	3. Our eyes see (perceive directly) objects in the light. Our eyes see pictures or images of objects that come to our eyes.	3. Our eyes see light that bounces off of objects.

Chart 2.

Pathways of Light

Children who believe in the naive conception think of objects as affecting vision rather than as affecting light.

TOPIC	NAIVE CONCEPTION	GOAL CONCEPTION
1. How light travels.	1. Light is a condition, existing in space.	1. Light travels in a straight line.
2. Translucent objects.	2. Nothing passes throught transparent objects when you see through them. Picture or images pass through transparent objects.	2. Light can pass straight through transparent objects.
3. Translucent objects.	3. Translucent objects blur images.	3. Light scatters when it passes through things that are translucent.
4. Opaque objects.	4. Opaque objects block vision. Opaque objects make shadows.	4. Light cannot pass through opaque objects. Shadows are left behind opaque objects when they stop light.
5. Mirrors.	5. Mirrors reflect pictures or images.	5. Mirrors reflect light in the same pattern to your eyes. Most objects scatter reflected light.

Chart 3.

Conceptions of Color

Children believing in a naive conception believe that we see the colors in objects, rather than seeing the color of reflected light.

	TOPIC		NAIVE CONCEPTION		GOAL CONCEPTION
1.	Nature of white and colored light.	1.	White light is pure and colorless.	1.	White light is a mixture of colors.
			Colored light is white light with color added.		The colors in white light are the colors of the spectrum.
			Colored light is a mixture of colors.		Colored light is pure--all one color.
2.	Interaction of light and colored objects.	3.	Objects have colors.	3.	Pigments in objects reflect one color of light.
		4.	Light reveals the colors of objects.	4.	Pigments in objects absorb other colors of light.
3.	How eyes see color.	5.	Our eyes see colors of objects.	5.	Our eyes detect (see) colored light.
4.	Nature of color.	6.	Color is not light but it can be added to light.	6.	Color is property of light only (not objects).
		7.	Colors mix according to artists' rules.	7.	Colors of light and pigments mix according to different rules.

Reference

Blecha, M.K., Gega, P.C., & Green, M. Exploring Science (Green Book, 2nd ed.). River Forest, Illinois: Laidlaw Brothers, 1979.